Scalable and Efficient Newton-Krylov Solution Methods for Multiple-time-scale MHD Systems

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This talk briefly summarizes our recent effort to develop efficient and scalable fully-implicit solution methods for resistive and extended MHD systems. These multiphysics systems are governed by highly-nonlinear, strongly-coupled PDEs that span a very large range of time- and length-scales. The interacting, multiple time-scale physical mechanisms can produce very complex dynamical behavior, making the stable, accurate, and efficient computational solution, over relevant time-scales of interest, extremely challenging.

This presentation will overview a number of the important solution methods that our research team is developing to apply in the large-scale parallel finite element and finite volume approximation of such systems. The solution methods include fully-implicit time integration, direct-to-steady-state solvers, and continuation, bifurcation and linear stability techniques enabled by Newton-type nonlinear solvers. The resulting large sparse linear systems that are generated by these methods are solved by the application of parallel preconditioned Krylov techniques. The scalable preconditioners include a physics-based multilevel technique and an aggressive-coarsening block AMG type method. Comparisons are presented with a common parallel preconditioner based on variable overlap additive Schwarz domain decomposition (DD) and ILU type sub-domain solvers. To demonstrate the capability of these methods, results are presented for representative MHD simulations that include MHD duct flows, hydro-magnetic Rayleigh-Bernard stability computations, an island coalescence magnetic reconnection problem and a kink instability in a Tokamak reactor geometry.

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